CHAPTER 2

PLANNING AND TECHNICAL ASSESSMENT

2.1 Planning Procedure

Adequate planning must precede any wastewater treatment system design to ensure selection of the most cost-effective process that is feasible for the situation under consideration. In many cases, guidelines or specifications for the planning procedure are provided by the agency responsible for the project. The purpose of this chapter is to present those aspects of the planning procedure that are either unique or require special emphasis because of land treatment.

Process selection for land treatment systems is more dependent on site conditions than are mechanical treatment alternatives. This can mean that there is a need for extensive and, in some cases, expensive site investigation and field testing programs. To avoid unnecessary effort and expense, a two-phase planning approach has been developed and adopted by most agencies concerned. As shown in Figure 2-1, Phase 1 involves identification of potential sites via screening of available information and experience. If potential sites for any of the land treatment processes are identified, the study moves into Phase 2. This phase includes field investigations and an evaluation of the alternatives.

2.2 Phase 1 Planning

Early during Phase 1, basic data that are common to all wastewater treatment alternatives must be collected and analyzed along with land treatment system requirements to determine whether land treatment is a feasible concept. If no limiting factors are identified that would eliminate land treatment from further consideration, the next steps are to identify potential land treatment sites and to evaluate the feasibility of each site.

2.2.1 Preliminary Data

Service area definition, population forecasts, wastewater quality and quantity projections, and water quality requirements are usually either specified or determined using procedures established by the responsible authority. With the exception of water quality requirements, the data are generally the same for all forms of wastewater treatment. A few aspects are specific to land treatment and are discussed in this section.

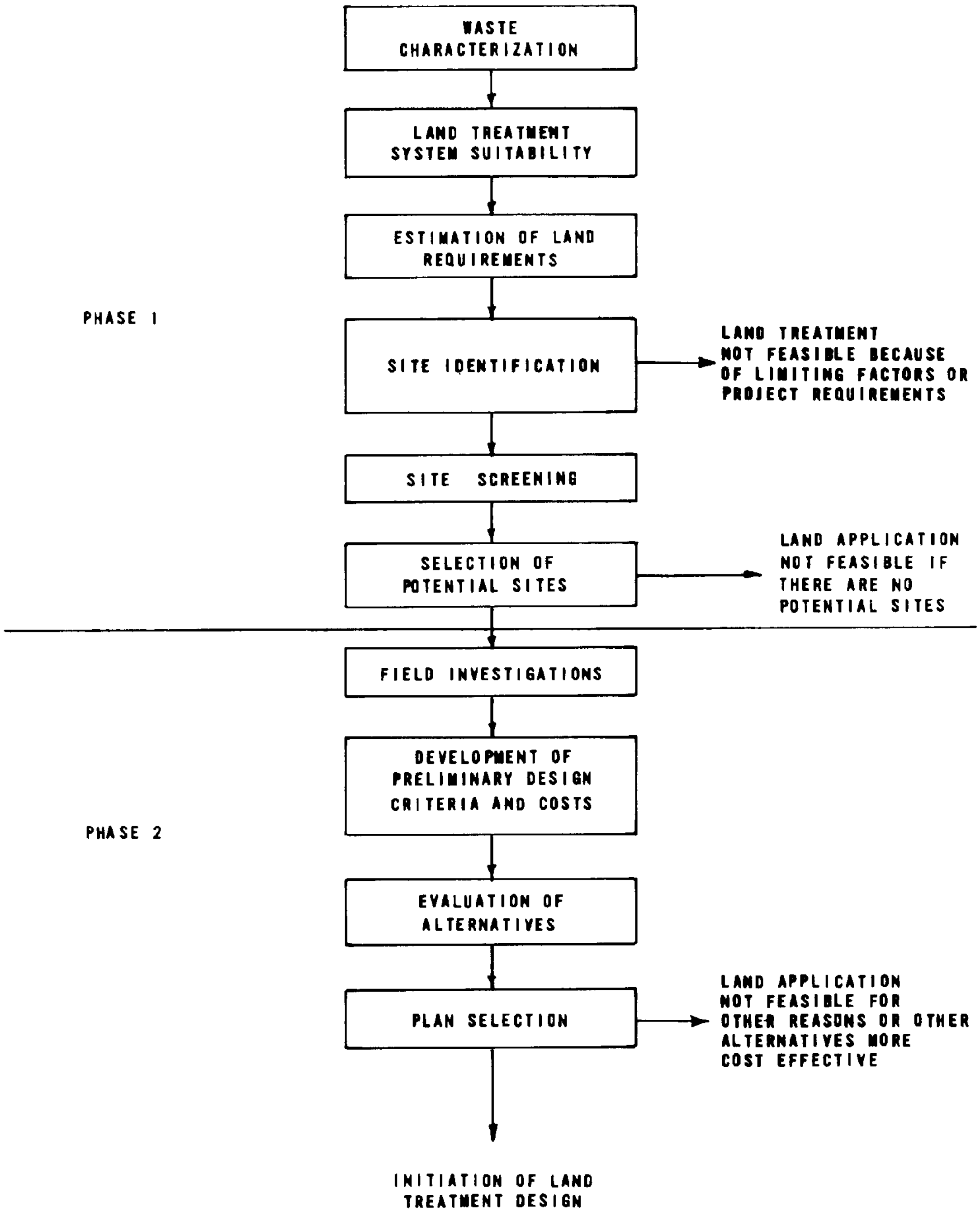


FIGURE 2-1
TWO-PHASE PLANNING PROCESS

2.2.1.1 Wastewater Quality and Loadings

Major constituents in domestic wastewater are presented in Table 2–1. Trace element concentration ranges are shown in Table 2–2. The values in these tables may be used for planning purposes when a community*s water quality has not been determined. Other important parameters in land treatment design can include total dissolved solids, pH, potassium, sodium, calcium, magnesium, boron, barium, selenium, fluoride, and silver.

TABLE 2-1
IMPORTANT CONSTITUENTS IN TYPICAL
DOMESTIC WASTEWATER [1]
mg/L

Constituent	Type of wastewater		
	Strong	Medium	Weak
BOD	400	220	110
Suspended solids	350	220	100
Nitrogen (total as N)	85	40	20
Organic	35	15	8
Ammonia	50	25	12
Nitrate	0	0	0
Phosphorus (total as P)	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Total organic carbon	290	160	80

For municipal land treatment systems, BOD and suspended solids loadings seldom limit system capacity. Typical BOD loading rates at municipal systems are shown in Table 2–3 and are much lower than rates used successfully in land treatment of food processing wastewaters. Suspended solids loadings at these industrial systems would be similar to the ROD loadings shown in Table 2–3.

In contrast, if nitrogen removal is required, nitrogen loading may limit the system capacity. Nitrogen removal capacity depends on the crop grown, if any, and on system management practices. The engineer should consult Sections 4.5 and 5.4.3.1 to determine whether nitrogen loading will govern system capacity and, therefore, land area requirements.

TABLE 2-2
COMPARISON OF TRACE ELEMENTS IN
WATER AND WASTEWATERS
mg/L

Element	Untreated wastewater[a]	Maximum recommended concentrations for irrigation water[b]	EPA recommended drinking water standards[c]
Arsenic	0.003	0.1	0.05
Boron	0.3-1.8	0.5-2.0	No standard
Cadmium	0.004-0.14	0.01	0.01
Chromium	0.02-0.700	0.1	0.05
Copper	0.02-3.36	0.2	1.0
Iron	0.9-3.54	5.0	0.3
Lead	0.05-1.27	5.0	0.05
Manganese	0.11-0.14	0.2	0.05
Mercury	0.002-0.044	No standard	0.002
Nickel	0.002-0.105	0.2	No standard
Zinc	0.030-8.31	2.0	5.0

a. The concentrations presented encompass the range of values reported in references [2-6].

b. Based on unlimited irrigation at 1.0 m/yr(3 ft/yr).

c. Reference [7].

TABLE 2-3
TYPICAL BOD LOADING RATES
kg/ha•yr

	Slow rate	Rapid infiltration	Overland flow
Range for municipal wastewater	370-1,830	8,000-46,000	2,000-7,500

Note: See Appendix G for metric conversions.

In some cases, other wastewater constituents such as phosphorus or trace elements may control design. For example, if wastewater trace element concentrations exceed the maximum recommended concentrations for irrigation water (Table 2–2), SR systems may be infeasible or may require special precautions. This is rare, however, and most municipal systems will be limited either by hydraulic capacity or nitrogen loading.

2.2.1.2 Water Quality Requirements

Land treatment systems have somewhat unique discharge requirements because many of these systems do not have conventional point discharges to receiving surface waters. In the past, the ability of the soil to treat wastewater was not well recognized. As a result, discharge standards were often imposed on a wastewater prior to its application on land, thereby increasing treatment costs and energy requirements without significantly improving overall treatment performance. More recently, land has been recognized as an important component in the treatment process. For this reason, discharge requirements now apply to water quality following land treatment.

For systems that discharge to receiving waters, such as OF systems and some underdrained or naturally draining SR and RI systems, renovated water quality must meet surface discharge requirements. For systems where the renovated water remains underground, EPA has established guidance for three categories of ground water discharge that meet the criteria for best practicable waste treatment. These three categories are as follows:

Case 1 - The ground water can potentially be used for drinking water supply.

The chemical and pesticide levels in Table 2–4 should not be exceeded in the ground water. If the existing concentration in the ground water of an individual parameter exceeds the standards, there should be no further increase in the concentration of that parameter resulting from land application of wastewater.

Case 2 - The ground water is used for drinking water supply.

The same criteria as Case 1 apply and the bacteriological quality criterion from Table 2–4 also applies in cases where the ground water is used without disinfection.

Case 3 - Uses other than drinking water supply.

Ground water criteria should be established by the Regional Administrator in conjunction with appropriate state agencies based on the present or potential use of the ground water.

For each ground water category, discharge requirements must be met at the boundary of the land treatment project.

TABLE 2-4
NATIONAL INTERIM PRIMARY
DRINKING WATER STANDARDS, 1977 [7,8]

Constituent or characteristic	Value[a]	Reason for standard
Physical		
Turbidity, units	1[b]	Aesthetic
Chemical, mg/L		
Arsenic	0.05	Health
Barium	1.0	Health
Cadmium	0.01	Health
Chromium	0.05	Health
Fluoride	1.4-2.4[c]	Health
Lead	0.05	Health
Mercury	0.002	Health
Nitrates as N	10	Health
Selenium	0.01	Health
Silver	0.05	Cosmetic
Sodium[d]	--	Health
Bacteriological		
Total coliforms, MPN/100 mL	1	Disease
Pesticides, mg/L		
Endrin	0.0002	Health
Lindane	0.004	Health
Methoxychlor	0.1	Health
Toxaphene	0.005	Health
2,4-D	0.1	Health
2,4,5-TP	0.01	Health

a. The latest revisions to the constituents and concentrations should be used.

b. Five mg/L of suspended solids may be substituted if it can be demonstrated that it does not interfere with disinfection.

c. Dependent on ambient air temperature; higher limits for lower temperatures.

d. Ground water drinking supplies must be monitored at least once every 3 years; surface water supplies must be monitored at least annually.

For SR systems, individual states often have additional, crop-specific preapplication treatment requirements. These requirements are usually based on the method of wastewater application, the degree of public contact with the site, and the disposition of the crop. For example, crops for human consumption generally require higher levels of preapplication treatment than forage crops.

Local and state water quality requirements may also apply to site runoff. Generally, all wastewater runoff must be contained onsite and reapplied or treated. Stormwater runoff requirements will vary from site to site and will depend on the expected quality of the runoff and the quality of local surface waters. State and local water quality agencies should be contacted for more specific requirements.

2.2.1.3 Regional Characteristics

Critical regional parameters include climate, surface water hydrology and quality, and ground water quality.

Climate

Local climate may affect (1) the water balance (and thus the acceptable wastewater hydraulic loading rate), (2) the length of the growing season, (3) the number of days per year that a land treatment system cannot be operated, (4) the storage capacity requirement, (5) the loading cycle of RI systems, and (6) the amount of stormwater runoff. For this reason, local precipitation, evapotranspiration, temperature, and wind values must be determined before design criteria can be established. Whenever possible, at least 10 years of data should be used to obtain these values.

Three publications of The National Oceanic and Atmospheric Administration (NOAA) provide sufficient data for most communities. The Monthly Summary of Climatic Data provides basic information, including total precipitation, temperature maxima and minima, and relative humidity, for each day of the month and every weather station in a given area. Whenever available, evaporation data are included. An annual summary of climatic data, entitled Local Climatological Data, is published for a small number of major weather stations. Included in this publication are the normals, means, and extremes of all the data on record to date for each station. The Climate Summary of the United States provides 10 year summaries of the monthly climatic data. Other data included are:

- Total precipitation for each month of the 10 year period.
- Mean number of days that precipitation exceeded 0.25 and 1.3 cm (0.10 and 0.50 in.) during each month
- Total snowfall for each month of the period
- Mean temperature for each month of the period
- Mean daily temperature maxima and minima for each month

! Mean number of days per month that the temperature was less than or equal to 0 °C (32 °F) or greater than or equal to 32.5 °C (90 °F)

A fourth reference that can be helpful is EPA*s Annual and Seasonal Precipitation Probabilities [9]. This publication includes precipitation probabilities for 93 stations throughout the United States.

Data requirements for planning purposes are summarized in Table 2-5. The amount of water lost by evapotranspiration should also be estimated, either by using pan evaporation data supplied by NOAA or by using theoretical methods (Section 4.3.2.3). The length of the growing season for perennial crops is usually assumed to be the number of continuous days per year that the maximum daily temperature is above freezing. Specific information on growing seasons can also be obtained from the local county agent.

TABLE 2-5
SUMMARY OF CLIMATIC ANALYSES

Factor	Data required	Analysis	Use
Precipitation	Annual average, maximum, minimum	Frequency	Water balance
Rainfall storm	Intensity, duration	Frequency	Runoff estimate
Temperature	Days with average below freezing	Frost free period	Storage, treatment efficiency, crop growing season
Wind	Velocity, direction	--	Cessation of sprinkling
Evapotran-spiration	Annual, monthly average	Annual distribution	Water balance

Surface Water Hydrology

For SR systems (see Chapter 4 for details) best management practices for control of stormwater should be used. Contour planting (instead of straight-row planting) and incorporating plant residues into the soil to increase the soil organic content will also minimize sediment and nutrient losses. When designing drainage and runoff collection systems, a 10 year return event should be the minimum interval considered.

Ground Water Hydrology

Information that should be obtained includes soil surveys, geologic and ground water resources surveys, well drilling logs, ground water level measurements, and chemical analyses of the ground water. Numerous federal, state, county, and city agencies have this type of information as well as universities, professional and technical societies, and private concerns with ground water related interests. Particularly good sources are the U.S. Geological Survey (USGS), state water resources departments, and county water conservation and flood control districts. Much of the information collected from these agencies and entities will also be useful during the site identification step. (Figure 2-1).

2.2.2 Land Treatment System Suitability

Factors that should be considered in determining suitability of a particular land treatment process are:

- Process ability to meet treatment requirements (refer to Chapter 1)
- Study area characteristics that may dictate or eliminate certain land treatment processes
- Secondary project objectives, such as a desire for increased water supplies for irrigation or recreation

Once a preliminary decision regarding process suitability has been made, typical hydraulic and nutrient loading rates can be used to estimate land area. Minimum preapplication treatment, storage, and other requirements are then determined, and the feasibility of each type of land treatment process is evaluated.

2.2.2.1 Process Loading Rates

<u>Slow Rate Process</u>

The amount of wastewater that can be applied to a given SR site per unit area and per unit time is the wastewater hydraulic loading rate, which can be estimated by using the following water balance equation:

$$\text{Precipitation} + \text{applied wastewater} = \text{evapotranspiration} + \text{percolation} \tag{2-1}$$

Runoff is not included in the equation since SR design is based on having no runoff of applied wastewater. The percolation rate is the volume of water that must travel through the soil, per unit application area and unit time, and is established during system design. To ensure that there is no runoff, the design percolation rate should never exceed the saturated hydraulic conductivity, or permeability, of the most restrictive layer in the soil profile (i.e., the minimum soil permeability), potential evapotranspiration values have been calculated for various locations in the United States.

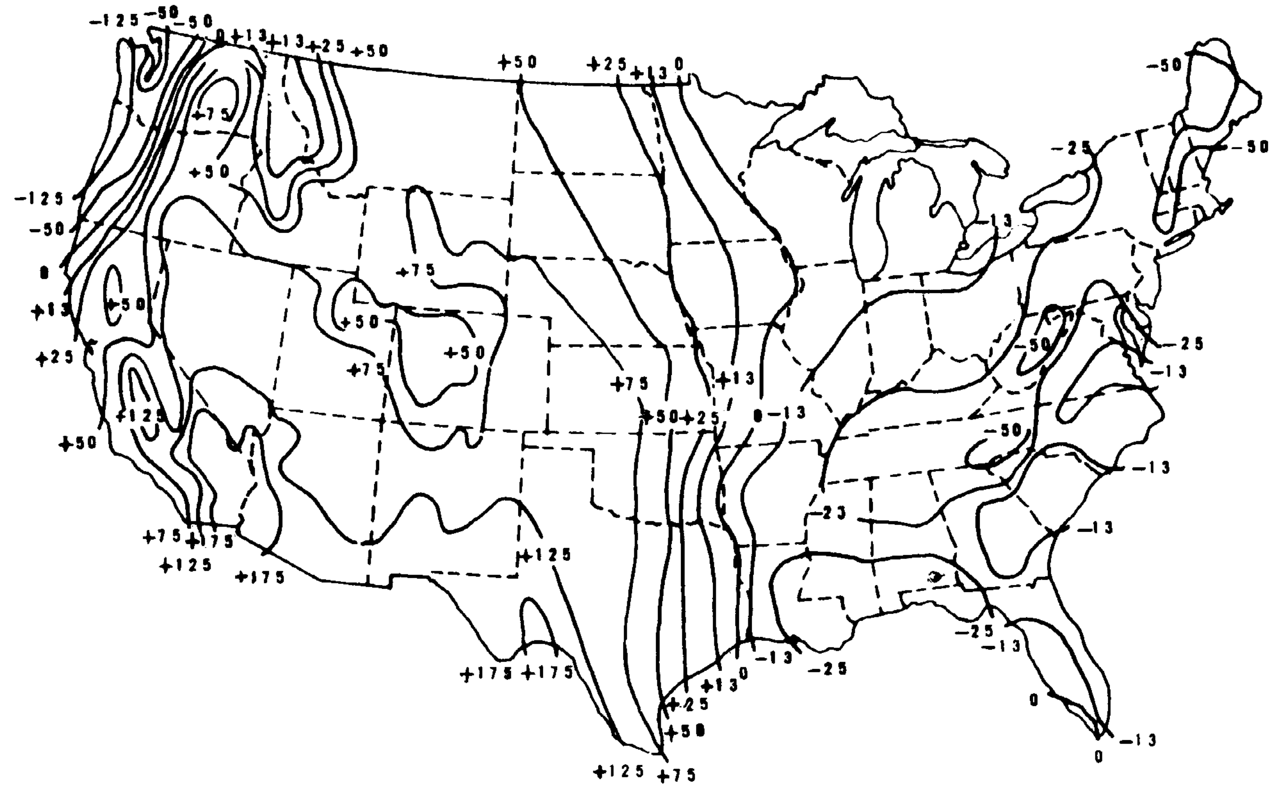
These evapotranspiration values have been used along with local precipitation records to plot the difference between potential evapotranspiration and precipitation as a function of location [10] . This plot, included as Figure 2-2, can be used to determine rough estimates of the difference between evapotranspiration and precipitation at any site in the mainland United States.

Experience has shown that the maximum design percolation rate should equal no more than a fraction of the minimum soil permeability or hydraulic conductivity measured with clear water and using typical field and laboratory procedures (Sections 3.4 and 3.5). For planning purposes, the fraction ranges from about 4 to 10% of the minimum hydraulic conductivity depending on the uniformity of the soil and the degree of conservativeness (Sections 4.5.1, 5.4.1). Based on this relationship, the recommended maximum percolation rate is plotted in Figure 2-3 as a function of minimum soil permeability as measured with clear water. To use the plot during Phase 1, soil permeability must be estimated from soil survey information. Then, the range of recommended maximum percolation rates is read from the graph. The recommended range of annual wastewater hydraulic loading rates is estimated using Equation 2-1, by adding the difference between evapotranspiration and precipitation (taken from Figure 2-2) to the range of percolation rates identified in Figure 2-3. During Phase 2, hydraulic conductivity measurements should be conducted at selected sites and used to estimate maximum percolation rates.

The range of percolation rates that have been used in practice is broader than the maximum recommended range shown in Figure 2-3. The range is greater because parameters other than soil hydraulic capacity, such as nitrogen loading, crop requirements, and climate, often limit the allowable percolation rate of SR systems. For preliminary planning purposes, loading rates and land requirements are estimated by assuming that corn or sorghum or forage grasses will be grown. Nitrogen requirements for these crops are discussed in Section 4.3.

<u>Rapid Infiltration Process</u>

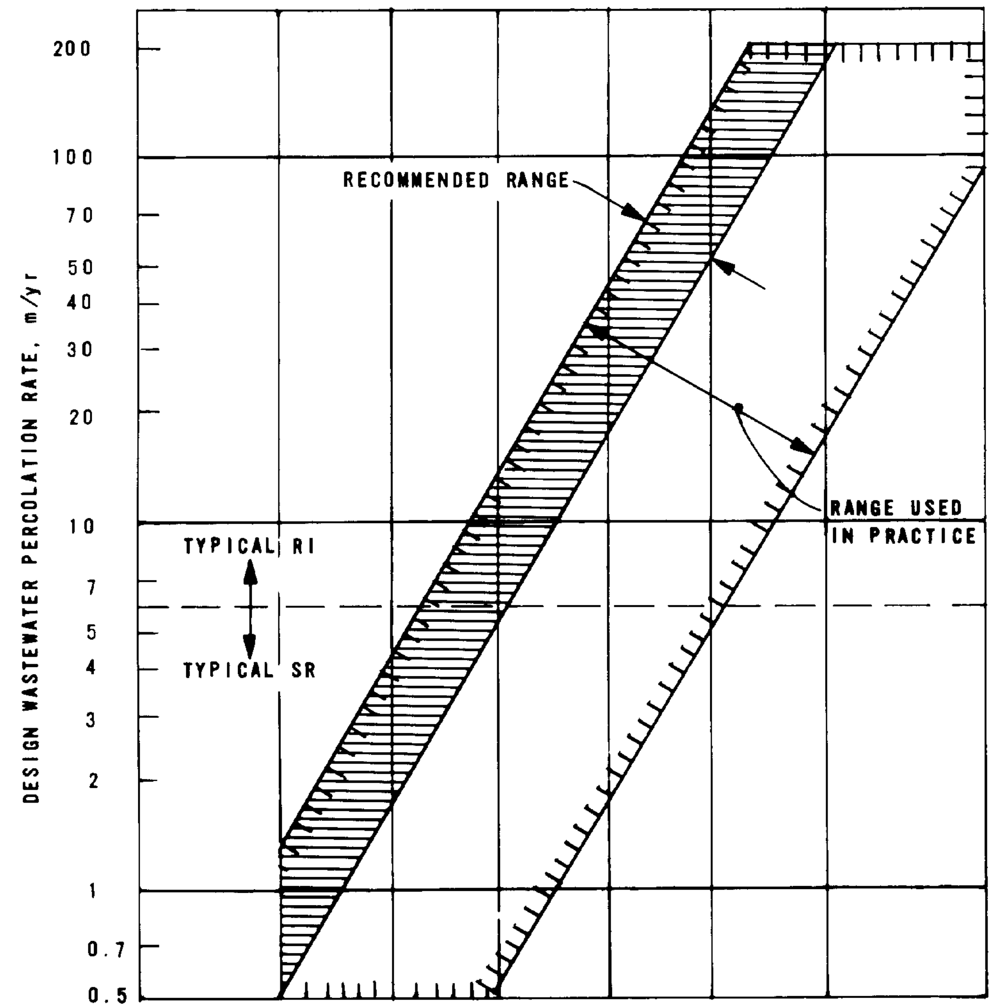
Wastewater hydraulic loading rates for RI systems are based on the hydraulic capacity of the soil and on the underlying soil geology. During phase 1, hydraulic capacity is estimated from soil survey data and other published sources. Then, the range of percolation rates to use during preliminary planning is read from Figure 2-3. This figure (2-3) should not be used for design.



\+ POTENTIAL EVAPOTRANSPIRATION MORE THAN MEAN ANNUAL PRECIPITATION

\- POTENTIAL EVAPOTRANSPIRATION LESS THAN MEAN ANNUAL PRECIPITATION

FIGURE 2-2
POTENTIAL EVAPOTRANSPIRATION VERSUS MEAN ANNUAL PRECIPITATION [10]
cm



	CLEAR WATER PERMEABILITY, SOIL CONSERVATION SERVICE DESCRIPTIVE TERMS						
UNITS	VERY SLOW	SLOW	MODERATE-LY SLOW	MODERATE	MODERATE-LY RAPID	RAPID	VERY RAPID
in./h	< 0.06	0.06-0.20	0.20-0.60	0.60-2.0	2.0-6.0	6.0-20.0	> 20.0
cm/h	< 0.15	0.15-0.51	0.51-1.5	1.5-5.1	5.1-15.2	15.2-50.8	> 50.8

PERMEABILITY OF MOST RESTRICTIVE LAYER IN SOIL PROFILE

FIGURE 2-3
ESTIMATED DESIGN PERCOLATION RATE AS A FUNCTION OF SOIL PERMEABILITY FOR SR AND RI LAND TREATMENT

During Phase 2, design percolation rates are determined by measuring at least one of the following parameters:

- Infiltration rate using appropriate tests (Section 3.4)

- Hydraulic conductivity (permeability) of the soil, usually in vertical direction

As described in Section 5.4.1, the design percolation rate will always be a fraction of the test results. Considerations of nutrient removal and cold weather operation may require adjustments in the design percolation rate.

Overland Flow Process

During Phase 1 and phase 2 planning, the engineer can assume a hydraulic loading rate of 6.3 to 20 cm/wk (2.5 to 8 in./wk) for screened raw wastewater and a rate of 10 to 25 cm/wk (4 to 10 in./wk) for primary effluent (Section 6.4). Often, OF is used to polish wastewater effluent from biological treatment processes. In such cases, assumed wastewater loading rates may be as high as 20 to 40 cm/wk (8 to 16 in./wk).

2.2.2.2 Storage Needs

For SR and OF systems, adequate storage must be provided when climatic conditions halt operations or require reduced hydraulic loading rates. Most RI basins are operated year-round, even in areas that experience cold winter weather (Figure 2-4). Rapid infiltration systems may require cold weather storage during periods when the temperature of the wastewater to be applied is near freezing and the ambient air temperature at the site is below freezing. Generally, the problem occurs only when ponds are used for preapplication treatment. Land treatment systems also may need storage for flow equalization, system backup and reliability, and system management, including crop harvesting (SR and OF) and spreading basin maintenance (RI). Reserve application areas can be used instead of storage for these system management requirements.

During the planning process, Figure 2-5 may be used to obtain a preliminary estimate of storage needs for SR and OF systems. This figure was developed from data collected and analyzed by the National Climatic Center in Asheville, North Carolina. The data were used to develop computer programs that estimate site specific wastewater storage requirements based on climate [11], which, in turn, were used to plot Figure 2-5. The map is based on the number of freezing days per year corresponding to a 20 year return period. If application rates are reduced during cold weather, additional storage may be required. Should there be a need for more detailed data, the engineer should contact:

Director
National Climatic Center
Federal Building
Asheville, North Carolina 28801
(704) 258–2850

Any communications should refer to computer programs EPA–l, 2, and 3 (Section 4.6.2 and Appendix F). Each of these programs costs $225 for an initial computer run (January 1981).

FIGURE 2-4
WINTER OPERATION OF RAPID INFILTRATION
AT LAKE GEORGE, NEW YORK

Alternatively, for OF and SR systems, -4 °C (25 °F) can be assumed as the minimum temperature at which a system will successfully operate. Readily available temperature data may

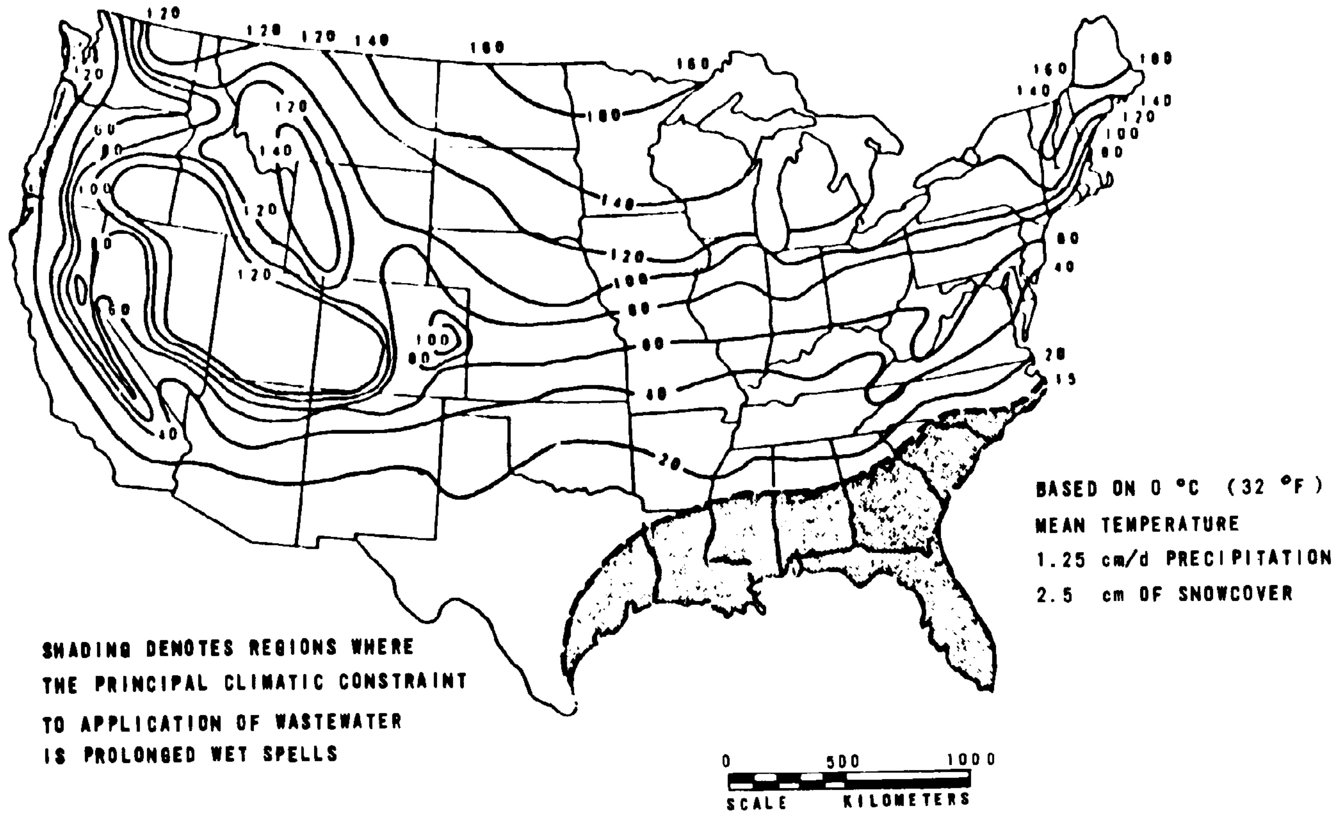


FIGURE 2-5
ESTIMATED WASTEWATER STORAGE DAYS BASED ONLY ON CLIMATIC FACTORS [11]

be used by assuming that systems do not operate below -4 °C. Then, the required storage volume is estimated from the average cold weather flow and the number of days in which the mean temperature is less than -4 °C.

2.2.3 Land Area Requirements

The amount of land required for a land treatment system includes the area needed for buffer zones, preapplication treatment, storage, access roads, pumping stations, and maintenance and administration buildings, in addition to the land actually required for treatment. Depending on growth patterns in the study area, and on the accessibility of the land treatment site, additional land may be required for future expansion or for plant emergencies.

During planning, the total amount of land required, excluding any buffer zones that may be required by state agencies, can be roughly approximated from Figure 2-6. To use the nomograph shown in this figure, the design wastewater flow must be known. First, the wastewater hydraulic loading rate is estimated (Section 2.2.2). Then, the wastewater flow and hydraulic loading rate are located on the appropriate axes and a line is drawn passing through them to the pivot line. Next, the number of weeks per year that the system will not operate, due to weather, crop harvesting, or other reasons, is estimated. A second line is drawn from the pivot point to the number of nonoperating weeks. The point at which this second line crosses the axis labeled “total area” corresponds to the estimated required area.

2.2.4 Site Identification

Potential land treatment sites are identified using existing soils, topography, hydro geology, and land use data, shown by parameter on individual study area maps. Eventually, the data are combined into composite study area maps that indicate areas of high, moderate, and low land treatment suitability.

Potential land treatment sites are identified using a deductive approach [13]. First, any constraints that might limit site suitability are identified. In most study areas, all land within the area should be evaluated for each land treatment process. The next step is to classify broad areas of land near the area where wastewater is generated according to their land treatment suitability. Factors that should be considered include current and planned land use, topography, and soils.

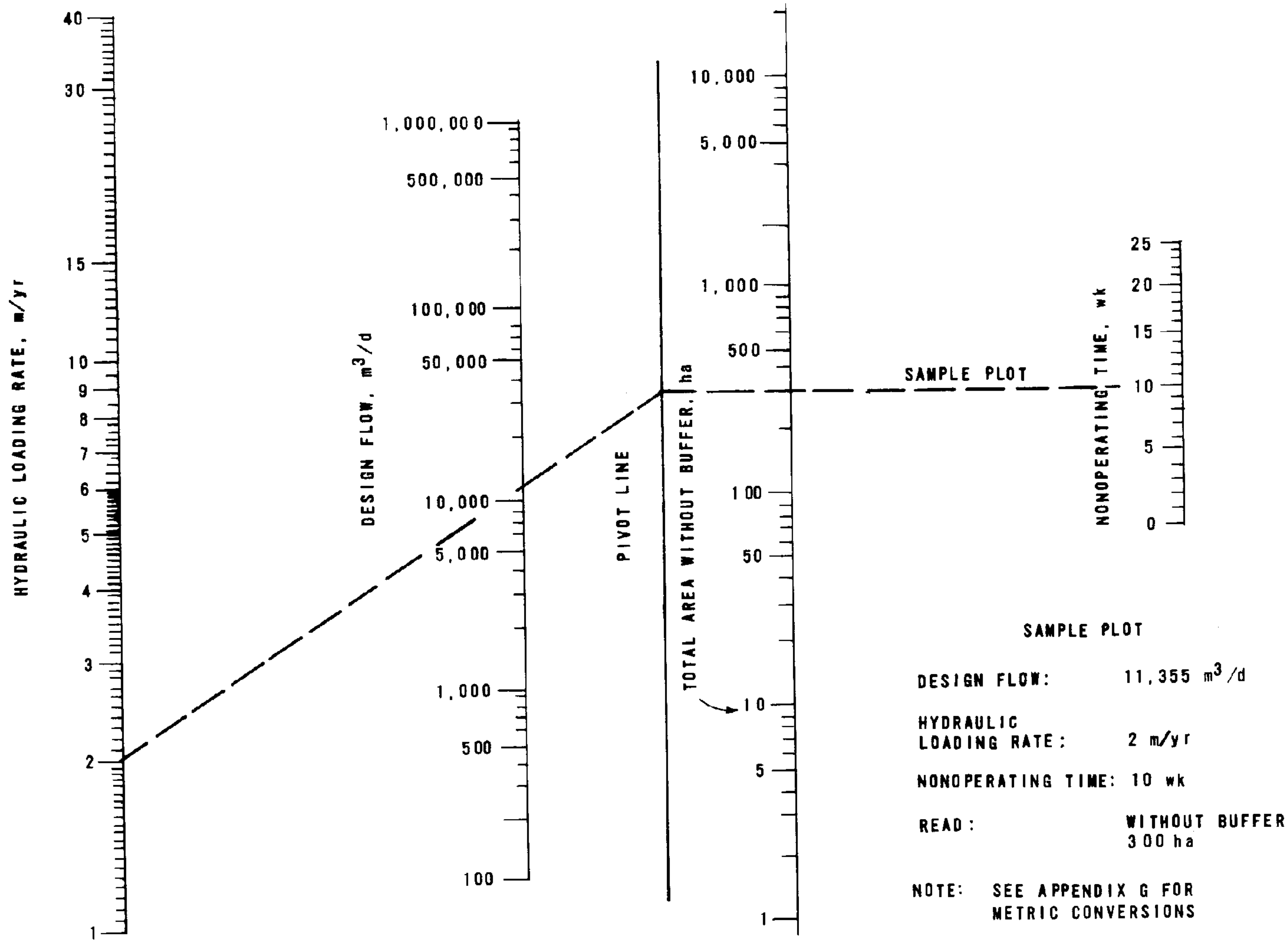


FIGURE 2-6
TOTAL LAND REQUIREMENT (INCLUDES LAND FOR APPLICATION, ROADS, STORAGE, AND BUILDINGS)

2.2.4.1 Land Use

Land use in most communities is regulated by local, county, and regional zoning laws. Land treatment systems must comply with the appropriate zoning regulations. For this reason, the planner should be fully aware of the actual land uses and proposed land uses in the study area. The planner should attempt to develop land treatment alternatives that conform to local land use goals and objectives.

Land treatment systems can conform with the following land use objectives:

- Protection of open space that is used for land treatment
- Production of agricultural or forest products using renovated water on the land treatment site
- Reclamation of land by using renovated water to establish vegetation on scarred land
- Augmentation of parklands by irrigating such lands with renovated water
- Management of flood plains by using flood plain areas for land treatment, thus precluding land development on such sites
- Formation of buffer areas around major public facilities, such as airports

To evaluate present and planned land uses, city, county, and regional land use plans should be consulted. Because such plans often do not reflect actual current land use, site visits are recommended to determine existing land use. Aerial photographic maps may be obtained from the Soil Conservation Service (SCS) or the local assessor*s office. Other useful information may be available from the USGS and the EPA, including true color, false color infrared, and color infrared aerial photos of the study area.

Once the current and planned land uses have been determined, they should be plotted on a study area map. Then, land use suitability may be plotted using the factors shown in Table 2-6.

Both land acquisition procedures and treatment system operation are simplified when few land parcels are involved and contiguous parcels are used. Therefore, parcel size is an important parameter. Usually, information on parcel size can be obtained from county assessor or county recorder maps. Again, the information should be plotted on a map of the study area.

TABLE 2-6
LAND USE SUITABILITY FACTORS FOR
IDENTIFYING LAND TREATMENT SITES [14]

Land use factor	Type of system: Agricultural slow rate	Forest slow rate	Overland flow	Rapid infiltration
Open or cropland	High	Moderate	High	High
Partially forested	Moderate	Moderately high	Moderate	Moderate
Heavily forested	Low	High	Low	Low
Built upon (residential, commercial, or industrial)	Low	Very low	Very low	Very low

2.2.4.2 Topography

Steep grades limit a site*s potential because the amount of runoff and erosion that will occur is increased, crop cultivation is made more difficult, if not impossible, and saturation of steep slopes may lead to unstable soil conditions. The maximum acceptable grade depends on soil characteristics and the land treatment process used (Table 1-2).

Grade and elevation information can be obtained from USGS topographic maps, which usually have scales of 1:24,000 (7.5 minute series) or 1:62,500 (15 minute series). Grade suitability may be plotted using the criteria listed in Table 2-7.

TABLE 2-7
GRADE SUITABILITY FACTORS FOR IDENTIFYING
LAND TREATMENT SITES [14]

Grade factor	Slow rate systems: Agricultural	Forest	Overland flow	Rapid infiltration
0 to 12%	High	High	High	High
12 to 20%	Low	High	Moderate	Low
>20%	Very low	Moderate	Eliminate	Eliminate

Relief is another important topographical consideration and is the difference in elevation between one part of a land treatment system and another. The primary impact of relief is its effect on the cost of conveying wastewater to the land application site. Often, the economics of pumping wastewater to a nearby site must be compared with the cost of constructing gravity conveyance to more distant sites.

A site*s susceptibility to flooding also can affect its desirability. The flooding hazard of each potential site should be evaluated in terms of both the possible severity and frequency of flooding as well as the areal extent of flooding. In some areas, it may be preferable to allow flooding of the application site provided offsite storage is available. Further, crops can be grown in flood plains if flooding is infrequent enough to make farming economical.

Overland flow sites can be located in flood plains provided they are protected from direct flooding which could erode the slopes. Backwater from flooding, if it does not last more than a few days, should not be a problem. Flood plain sites for RI basins should be protected from flooding by the use of levees.

Summaries of notable floods and descriptions of severe floods are published each year as the USGS Water Supply Papers. Maps of certain areas inundated in past floods are published as Hydrologic Investigation Atlases by the USGS. The USGS also has produced more recent maps of flood prone areas for many regions of the county as part of the Uniform National Program for Managing Flood Losses. These maps are based on standard 7.5 minute (1:24,000) topographic sheets and identify areas that lie within the 100 year flood plain. Additional information on flooding susceptibility is available from local offices of the U.S. Army Corps of Engineers and local flood control districts.

2.2.4.3 Soils

Common soil-texture terms and their relationship to the SCS textural class names are listed in Table 2-8.

Fine-textured soils do not drain well and retain water for long periods of time. Thus, infiltration is slower and crop management is more difficult than for freely drained soils such as loamy soils. Fine-textured soils are best suited for the OF process. Loamy or medium-textured soils are desirable for the SR process, although sandy soils may be used with certain crops that grow well in rapidly draining soils. Soil structure and soil texture are important characteristics that relate to permeability and acceptability for land treatment.

Structure refers to the degree of soil particle aggregation. A well structured soil is generally more permeable than unstructured material of the same type. The RI process is suited for sandy or loamy soils.

TABLE 2-8
SOIL TEXTURAL CLASSES AND GENERAL TERMINOLOGY USED IN SOIL DESCRIPTIONS

General terms		Basic soil textural class names
Common name	Texture	
Sandy soils	Coarse	Sand Loamy sand
	Moderately coarse	Sandy loam Fine sandy loam
Loamy soils	Medium	Very fine sandy loam Loam Silt loam Silt
	Moderately fine	Clay loam Sandy clay loam Silty clay loam
Clayey soils	Fine	Sandy clay Silty clay Clay

Soil surveys are usually available from the SCS. Soil surveys normally contain maps showing soil series boundaries and textures to a depth of about 1.5 m (5 ft). The scale of these maps ranges from 1:31,680 to 1:15,840 and even 1:7,920 in some locations. In a survey, limited information on chemical properties, grades, drainage, erosion potential, general suitability for locally grown crops, and interpretive and management information is provided. In some areas, published surveys are not available or exist only as detailed reports with maps ranging in scale from 1:100,000 to 1:250,000. Additional information on soil characteristics and on soil survey availability can be obtained from the SCS, through the local county agent.

Although soil depth, permeability, and chemical characteristics significantly affect site suitability, data on these parameters are often not available before the site investigation phase. If these data are available, they should be plotted on a study area map along with soil texture. In identifying potential sites, the planner should keep in mind that adequate soil depth is needed for root development and for thorough wastewater treatment. Further, permeability requirements vary among the land treatment processes. Desirable permeability ranges are shown by process in Table 2-9 together with desired soil texture. The SCS permeability class definitions are presented in Figure 2-3.

Certain geological formations are of interest during Phase 1. Discontinuities and fractures in bedrock may cause shortcircuiting or other unexpected ground water flow patterns. Impermeable or semipermeable layers of rock, clay, or hardpan can result in perched ground water tables. The USGS and many state geological surveys have maps indicating the presence and effects of geological formations. These maps and other USGS studies may be used to plot locations within the study area where geological formations may limit the suitability for land treatment.

TABLE 2-9
TYPICAL SOIL PERMEABILITIES AND TEXTURAL
CLASSES FOR LAND TREATMENT PROCESSES

	Principal processes		
	Slow rate	Rapid infiltration	Overland flow
Soil permeability range, cm/h	>0.15	>5.0	<0.5
Permeability class range	Moderately slow to moderately rapid	Rapid	Slow
Textural class range	Clay loams to sandy loams	Sand and sandy loams	Clays and clay loams
Unified Soil Classification	GM-d, SM-d, ML, OL, MH, PT	GW, GP, SW, SP	GM-u, GC, SM-u, SC, CL, OL, CH, OH

Once each of the parameters discussed in the preceding paragraphs have been mapped, the maps are merged into a composite map that indicates areas with high, moderate, and low suitability. Map overlays may be useful during this process.

2.2.5 Site Screening

During the latter half of Phase 1, each part of the study area that appears to be suitable for land treatment must be evaluated and rated in terms of technical suitability and feasibility. Rating is often accomplished by weighting each of the site selection factors and using a numerical system. The resulting ratings are used to identify sites that have high overall suitability and that should be investigated more thoroughly. If suitable sites are not available, no further consideration is given to land treatment.

Site selection factors and weightings should vary to suit the needs and characteristics of the community. Several factors that should be considered are listed in Table 2-10. A sample rating system is shown in Table 2-11. This system may be varied by the planner to reflect available information.

TABLE 2-10
SITE SELECTION GUIDELINES

Characteristic	Process	Remarks
Soil permeability	Overland flow	High permeability soils are more suitable to other processes.
	Rapid infiltration and slow rate	Hydraulic loading rates increase with permeability.
Potential ground water pollution	Rapid infiltration and slow rate	Affected by the (1) proximity of the site to a potential potable aquifer, (2) presence of an aquiclude, (3) direction of ground water flow, and (4) degree of ground water recovery by wells or underdrains.
Ground water storage and recovery	Rapid infiltration	Capability for storing percolated water and recovery by wells or underdrains is based on aquifer depth, permeability, aquiclude continuity, effective treatment depth, and ability to contain the recharge mound within the defined area.
Existing land uses	All processes	Involves the occurrence and nature of conflicting land use.
Future land use	All processes	Future urban development may affect the ability to expand the system.
Size of site	All processes	If there are a number of small parcels, it is often difficult to purchase or lease the needed area.
Flooding hazard	All processes	May exclude or limit site use.
Slope	All processes	Steep grades may (1) increase capital expenditures for earthwork, and (2) increase the erosion hazard during wet weather.
	Rapid infiltration	Steep grades often affect ground water flow pattern.
	Overland flow	Steep grades reduce the travel time over the treatment area and treatment efficiency. Flat land requires extensive earthwork to create grades.
Water rights	All processes	May require disposal of renovated water in a particular watershed within a particular stretch of surface water.

TABLE 2-11
RATING FACTORS FOR SITE SELECTION [14, 15]

Characteristic	Slow rate systems: Agricultural	Slow rate systems: Forest	Overland flow	Rapid infiltration
Soil depth, m[a]				
0.3-0.6	E[b]	E	0	E
0.6-1.5	3	3	4	E
1.5-3.0	8	8	7	4
>3.0	9	9	7	8
Minimum depth to ground water, m				
<1.2	0	0	2	E
1.2-3.0	4	4	4	2
>3.0	6	6	6	6
Permeability, cm/h[c]				
<0.15	1	1	10	E
0.15-0.5	3	3	8	E
0.5-1.5	5	5	6	1
1.5-5.0	8	8	1	6
>5.0	8	8	E	9
Grade, %				
0-5	8	8	8	8
5-10	6	8	5	4
10-15	4	6	2	1
15-20	0	5	E	E
20-30	0	4	E	E
30-35	E	2	E	E
>35	E	0	E	E
Existing or planned land use				
Industrial	0	0	0	0
High density residential/urban	0	0	0	0
Low density residential/urban	1	1	1	1
Forested	1	4	1	1
Agricultural or open space	4	3	4	4
Overall suitability rating[d]				
Low	<15	<15	<16	<16
Moderate	15-25	15-25	16-25	16-25
High	25-35	25-35	25-35	25-35

Note: The higher the maximum number in each characteristic, the more important the characteristic; the higher the ranking, the greater the suitability.

a. Depth of the profile to bedrock.

b. Excluded; rated as poor.

c. Permeability of most restrictive layer in soil profile.

d. Sum of values.

EXAMPLE 2-1: USE OF RATING FACTORS TO DETERMINE SITE SUITABILITY

An example of the use of rating factors is presented in the following two figures and tables. Example soil types are shown in Figure 2-7 as presented in a portion of a county SCS soil survey. Characteristics of the three soil types and existing land uses are presented in Table 2-12. The characteristics are then compared to the rating factors in Table 2-11 to obtain the numerical values in Table 2-13. For example, the Bibb silt loam in Table 2-12 has a depth of soil above bedrock of 1.5 to 3 m (5 to 10 ft). From Table 2-11, this would correspond to values of 8 for SR, 7 for OF, and 4 for RI. These values are entered into Table 2-13.

When all factors are evaluated, the numerical values are added together to obtain a total and to determine the suitability rating. The high suitability areas are presented in the soils map in Figure 2-8. By applying this procedure to all soils within a given radius of the community, the most suitable sites (generally 3 to 5) are identified for further field investigation and cost—effectiveness evaluation.

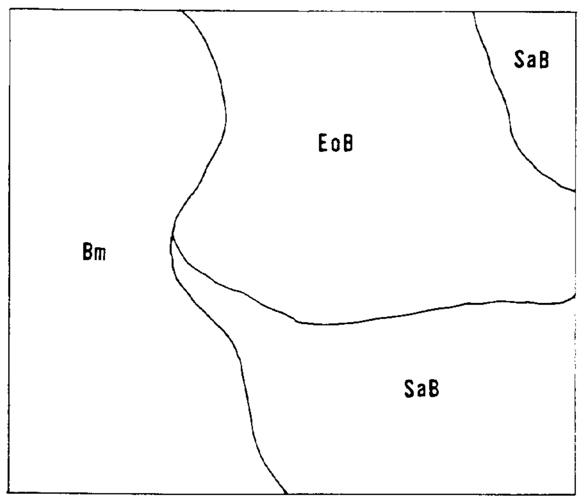


FIGURE 2-7
EXAMPLE AREA OF SOIL MAP TO BE EVALUATED

TABLE 2-12
CHARACTERISTICS OF SOIL SERIES MAPPED IN FIGURE 2-7

	Bibb silt loam	Sassafras fine sandy loam	Evesboro loamy sand
Map symbol	Bm	SaB	EoB
Soil depth, m	1.5-3.0	0.6-1.5	>3.0
Depth to ground water, m	<1.2	1.2-3.0	1.2-3
Permeability, cm/h	<0.15	1.5-5.0	>5.0
Grade, %	0-5	0-5	0-5
Land use	Agricultural	Forested	Industrial

TABLE 2–13
EXAMPLE USE OF RATING FACTORS FOR SITE SELECTION

Soil type	System type	Depth	Ground water	Perme-ability	Grade	Land use	Total	Suitability
Bibb	SR	8	0	1	8	4	21	Moderate
silt loam	OF	7	2	10	8	4	31	High
(Bm)	RI	4	E	E	8	4	--[a]	Eliminate
Sassafras	SR	2	4	8	8	1	24	Moderate
fine sandy	OF	4	4	1	8	1	18	Moderate
loam (SaB)	RI	E	2	6	8	1	--[a]	Eliminate
Evesboro	SR	9	4	8	8	0	29	High
loamy sand	OF	7	4	E	8	0	--[a]	Eliminate
(EoB)	RI	8	2	9	8	0	27	High

a. Total not determined because site was clearly eliminated (E) for this type of land treatment based on one or more site factors.

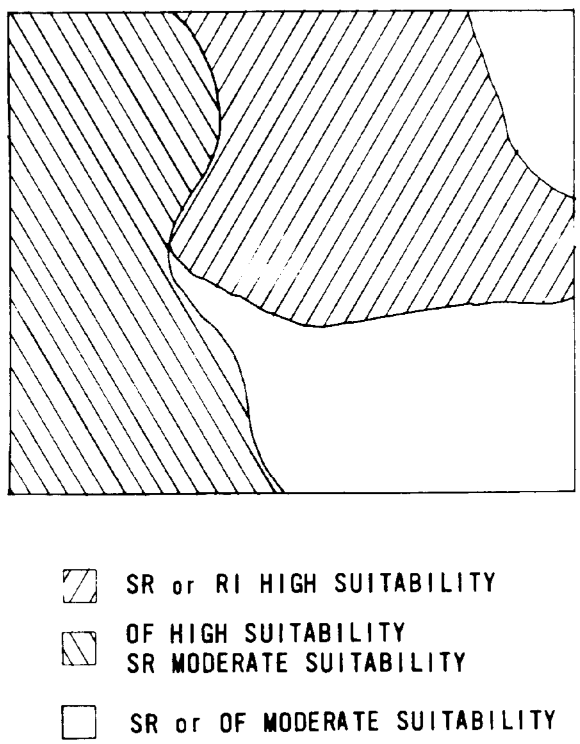


FIGURE 2-8
EXAMPLE SUITABILITY MAP FOR SOILS IN FIGURE 2-7

2.3 Phase 2 Planning

Phase 2, the site investigation phase, occurs only if sites with potential have been identified in Phase 1. During Phase 2, field investigations are conducted at the selected sites to determine whether land treatment is technically feasible. When sufficient data have been collected, preliminary design criteria are calculated for each potential site. Using these criteria, capital and operation and maintenance costs are estimated. These cost estimates and other nonmonetary factors are used to evaluate the sites selected during Phase 1 for cost effectiveness. On the basis of this evaluation, a land treatment alternative is selected for design.

2.3.1 Field Investigations

Field investigations that should be performed during Phase 2 include:

- Characterization of the soil profile to an approximate depth of 1.5 m (5 ft) for SR, 3 m (10 ft) for RI, and 1 m (3 ft) for OF
- Measurements of ground water depth, flow, and quality
- Infiltration rate and soil hydraulic conductivity measurements
- Determination of soil chemical properties

Methods for these analyses are detailed in Chapter 3.

2.3.2 Selection of Preliminary Design Criteria

From information collected during the field investigations, the engineer can confirm the suitability of the sites for the identified land treatment process(es). Using the loading rates described previously (Figure 2-3, Section 2.2.2), the engineer should then select the appropriate hydraulic loading rate for each land treatment process that is suitable for each site under consideration. Based on the loading rate estimates, land area, preapplication treatment, storage, and other system requirements can be estimated. Reuse/recovery options should also be outlined at this time.

2.3.2.1 Preapplication Treatment

Some degree of wastewater treatment prior to land application is usually necessary, for one or more of the following reasons:

- To avoid unnecessary wear on the distribution system, and in particular, pumps in the system
- To allow wastewater storage prior to land treatment without creating nuisance conditions
- To minimize potential public health risks
- To reduce soil clogging in RI land treatment
- To obtain a higher overall level of wastewater treatment

Industrial pretreatment should be considered when industrial waste contains materials that (1) could hinder the treatment processes; (2) could accumulate in quantities that would be detrimental to the soil-plant system; or (3) could pass through a land treatment system and restrict the beneficial uses of the renovated water or the native ground water. Industrial contaminants of concern include trace organics and trace elements. General guidelines and time schedules for implementation of industrial waste pretreatment programs can be obtained from the EPA regional offices.

2.3.2.2 Recovery of Renovated Water

The collection of renovated wastewater following land treatment may be either necessary or desirable. If the renovated wastewater can be reclaimed for beneficial uses, recovery may even be profitable. In many locations, water rights may necessitate recovery of renovated water for disposal at a specific location in a given watershed. In some locations, underdrainage may be needed to control ground water elevations and allow site development.

Methods used to recover renovated wastewater include underdrains, recovery wells, surface runoff collection, and tailwater return. Wastewater can also be recovered through springs and seeps that result from land treatment or by subsurface flow from the land treatment site to the surface water. These methods and their applicability to each of the three major types of land treatment are summarized in Table 2-14. Design of recovery systems is discussed in more detail in Chapters 4, 5, and 6.

TABLE 2-14
APPLICABILITY OF RECOVERY SYSTEMS FOR RENOVATED WATER

Recovery system	Slow rate	Rapid infiltration	Overland flow
Springs, seeps, or natural drainage	Often used to maintain water rights	Often used to maintain water rights	NA
Underdrains	Ground water control and effluent reuse	Ground water control and effluent reuse	NA
Recovery wells	Usually NA	Ground water control and effluent reuse	NA
Surface runoff			
Effluent	NA	NA	Collect, discharge[a]
Stormwater	Sediment control	NA	Collect, discharge[a]
Tailwater			
Sprinkler application	NA	NA	NA
Surface application	25-50% of applied flow	NA	NA

NA - not applicable.

a. Disinfect if required before discharge; provide for short-term recycling of wastewater after extended periods of shutdown if effluent requirements are stringent.

2.3.3 Evaluation of Alternatives

Land treatment alternatives should be evaluated on the basis of capital costs, operation and maintenance costs (including energy consumption), and other nonmonetary factors, such as public acceptability, ease of implementation, environmental impact, water rights, and treatment consistency and reliability.

2.3.3.1 Costs

For cost analyses, the EPA cost-effectiveness analysis procedures described in 40CFR 35, Appendix A, must be used in selecting any municipal wastewater management system that will be funded under PL 92-500 [16]. For nongrant funded projects, the EPA analysis may be modified to fit a community*s specific objectives. The most cost-effective alternative is defined as follows [16]

> The most cost-effective alternative shall be the waste treatment management system which the analysis determines to have the lowest present worth or equivalent annual value unless nonmonetary costs are overriding. The most cost-effective alternative must also meet the minimum requirements of applicable effluent limitations, groundwater protection, or other applicable standards established under the Act.

Curves for estimating capital and operation and maintenance costs may be found in reference [17], or the CAPDET system can be used for a preliminary estimate.

Cost comparisons should include the cost of preapplication treatment and sludge handling as well as land treatment process components, including transmission, storage, field preparation, renovated water recovery, and land. The costs of resolving any water rights problems also must be included. The EPA cost-effectiveness guidelines require that grant-funded projects use the following general service lives:

!	Land	Permanent
!	Structures	30 to 50 years
!	Process equipment	15 to 30 years
!	Auxiliary equipment	10 to 15 years

Capital costs for land will vary from site to site. Land treatment systems must have adequate land for preapplication treatment facilities, storage reservoirs, wastewater application, buffer zones, administrative and laboratory buildings, transmission pipe easement, and other facilities. Costs of relocating residences and other buildings depend on the location but also should be included in capital cost estimates. The local offices of the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and state highway departments can provide information on relocation cost estimates.

Several options are available for acquisition or control of the land used for wastewater application, including:

! Outright purchase (fee-simple acquisition)

! Long-term lease or easement

! Purchase and leaseback of land (usually to farmer for irrigation) with no direct municipal involvement in land management.

For larger projects, fee-simple land acquisition is favored by most federal agencies, states, and communities. Further, outright purchase provides the highest degree of control over the land application site and ensures uninterrupted land availability. Estimates indicate that land leasing has been cost effective for several hundred projects nationwide. Generally, these projects are in arid or semiarid areas where renovated water has a high value and land a relatively low value. Leasing or easement arrangements also can be very attractive for smaller communities.

Capital costs of land for both land treatment processes and storage prior to land application are eligible for federal Construction Grants Program funding as specified in EPA guidance [18]. During the cost effectiveness analyses, the engineer must keep in mind that, unlike many other treatment components, land has a salvage value. In addition, current EPA guidance allows the land value to appreciate 3% per year. Thus, the salvage value after 20 years is:

$$(1 + 0.03)^{20} \times \text{present price} = (1.806)\ (\text{present price})$$

The present worth of this salvage value is calculated using the prevailing interest rate, not the 3% appreciation rate. Long-term easements or leases of land for land application processes also are eligible for Construction Grants Program funding, provided that the conditions summarized in Table 2-15 are met.

TABLE 2-15
LEASE/EASEMENT REQUIREMENTS FOR CONSTRUCTION GRANTS PROGRAM FUNDING [18]

- Limit the purpose of the lease or easement to land application and activities incident to land application.
- Describe explicitly the property use desired.
- Waive the landowner*s right to restoration of the property at the termination of the lease/easement.
- Recognizing the serious risk of premature lease termination, provide for full recovery of damages by the grantee in such an event. The grantee must insure the capability to operate and meet permit requirements for the useful life of the project.
- Provide for payment of the lease/easement in a lump sum for the full value of the entire term.
- Provide for leases/easements for the useful life of the treatment plant, with an option of renewal for additional terms, as deemed appropriate.

Operation and maintenance costs include labor, materials, and supplies (including chemicals), and power costs. For cost comparison purposes, they are assumed to be constant during the planning period. However, if average wastewater flows are expected to increase significantly during the planning period, operation and maintenance costs should be developed for each year of the planning process. Operation and maintenance cost curves may be found in references [17, 19].

To estimate labor costs, staffing requirements for both preapplication treatment and land treatment must be determined. Staffing requirements for preapplication treatment can be found in reference [19]. Staffing requirements at municipally owned and operated land treatment systems have been plotted as a function of flow in Figure 2-9. Land treatment systems that are owned and/or operated by farmers will have lower municipal staffing requirements.

Annual costs should include the cost of leasing land for wastewater application, when appropriate. Annual cost estimates also should take into consideration revenues from crop sales, sale of renovated water, sale of effluent for land application, or leaseback of purchased land for farming or other purposes. Because of the uncertainty in estimating these revenues, they should be used to offset only a portion of the operating costs in the cost-effectiveness analysis.

Prevailing market values for crops usually can be obtained from state university cooperative extension services. Preliminary yield estimates should be based on the proposed application conditions and on typical yields in the local area.

Another source of revenue may be the sale of recovered renovated water, particularly runoff from OF systems or renovated water from RI system recovery wells. Markets for renovated water must be investigated on a community by community basis. Methods of assessing the relative value of renovated wastewater for various uses and potential reuse categories are discussed in reference [20]

2.3.3.2 Energy

Basic energy requirements for unit processes and operations have been described and quantified in reference [21]. The data in the report were used to compare land treatment energy requirements with mechanical system requirements and to develop equations for calculating the energy requirements of each unit process [22] . Equations in Chapter 8 can be used to generate accurate power cost estimates for the cost-effectiveness analysis.

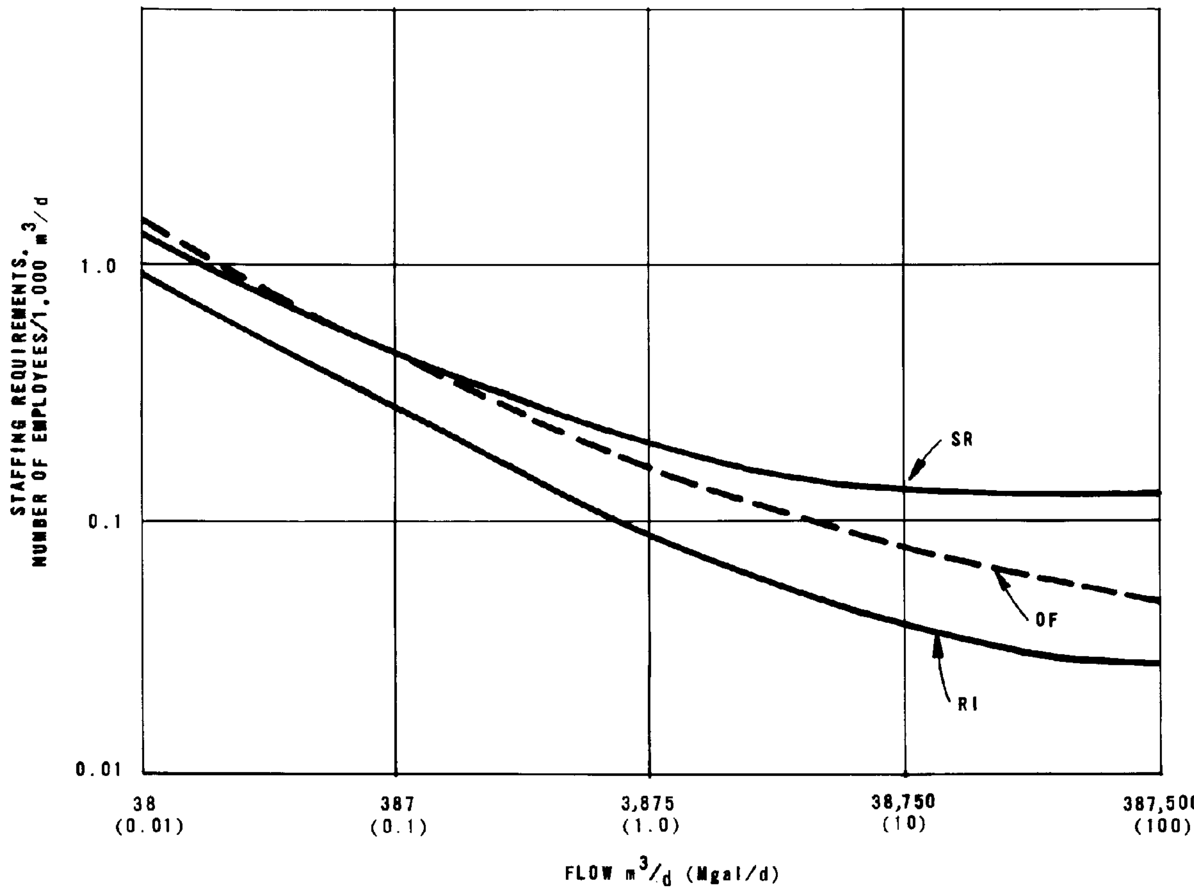


FIGURE 2-9
STAFFING REQUIREMENTS FOR LAND TREATMENT COMPONENTS (NOT INCLUDING SEWER SYSTEM OR PREAPPLICATION TREATMENT) FOR MUNICIPALLY OWNED AND OPERATED SYSTEMS [19]

2.3.3.3 Nonmonetary Considerations

According to the EPA guidelines, a cost-effectiveness analysis must also consider nonmonetary factors such as environmental impacts [23, 24], ease of implementation (magnitude of potential water rights conflicts, public acceptability), and treatment consistency and reliability. Potential water rights conflicts are discussed briefly in Section 2.4. Public acceptability will be greatly aided by an effective public participation program, particularly if there is any chance that local farmers will be involved in an SR system. Public participation regulations in the federal Construction Grants Program are given in 40 CFR Part 35. These regulations implement the public participation requirements of 40 CFR Part 25.

Changing discharge requirements, wastewater characteristics, growth rates, and land uses for areas surrounding and contributing to the treatment system require treatment flexibility. The ability of each alternative to adapt to changes should be evaluated.

2.3.4 Plan Selection

To select an alternative, each of the factors considered during the evaluation process should be compared on an equivalent basis. Monetary factors should be expressed in terms of total present worth or equivalent annual cost. Nonmonetary factors should be weighted according to their local importance, and reasons cited for abandoning any alternative for nonmonetary reasons. If there are no overriding nonmonetary factors, the alternative selected should be the plan with the lowest total present worth or equivalent annual cost.

Actual alternative selection should involve the wastewater management agency, the planner/engineer, advisory groups, citizen and special interest groups, and other interested governmental agencies. Once an alternative is tentatively selected, and before design begins, mitigation measures for minimizing any identified adverse impacts should be outlined.

2.4 Water Rights and Potential Water Rights Conflicts

Land application of wastewaters may cause several changes in drainage and flow patterns [25]:

1. Site drainage may be affected by land preparation, soil characteristics, slope, method of wastewater application, cover crops, climate, buffer zones, and spacing of irrigation equipment.

2. Land application may alter the pattern of flow in the body of water that would have received the wastewater discharge. Although this may diminish the flow in the body of water, it also may increase the quality. The change may be continuous or seasonal.

3. Land application may cause surface water diversion, because wastewaters that previously would have been carried away by surface waters are now applied to land and often diverted to a different watershed.

Two basic types of water rights laws exist in the United States: riparian laws, which emphasize the right of riparian landowners along a watercourse to use of the water, and appropriative laws, which emphasize the right of prior users of the water [25] . Most riparian or land ownership rights are in effect east of the Mississippi River, whereas most appropriative rights are in effect west of the Mississippi River. Specific areas where these two doctrines dominate are shown in Figure 2-10.

Most states divide their water laws into three categories: (1) waters in well-defined channels or basins (natural watercourses), (2) superficial waters not in channels or basins (surface waters), and (3) underground waters not in well-defined channels or basins (percolating waters or ground waters). Potential water rights problems involving each type of water and each of the three primary types of land treatment are summarized in Table 2-16. This table is intended to aid during planning and preliminary screening of alternatives, but is not to be used as the basis for eliminating any alternatives.

2.4.1 Natural Watercourses

Most legal problems regarding natural watercourses involve the diversion of a discharge with the subsequent reduction in flow through the watercourse. In riparian states, diversion of discharges that were not originally part of a stream should not be cause for legal action. In appropriative states, if the diversion would threaten the quantity or quality of a downstream appropriation, the downstream user has cause for legal action. Legal action may be either injunctive, preventing the diverter from affecting the diversion, or monetary, requiring the diverter to compensate for the damages. If the area is not water-short and if the watercourse is not already overappropriated, damages would be difficult if not impossible to prove.

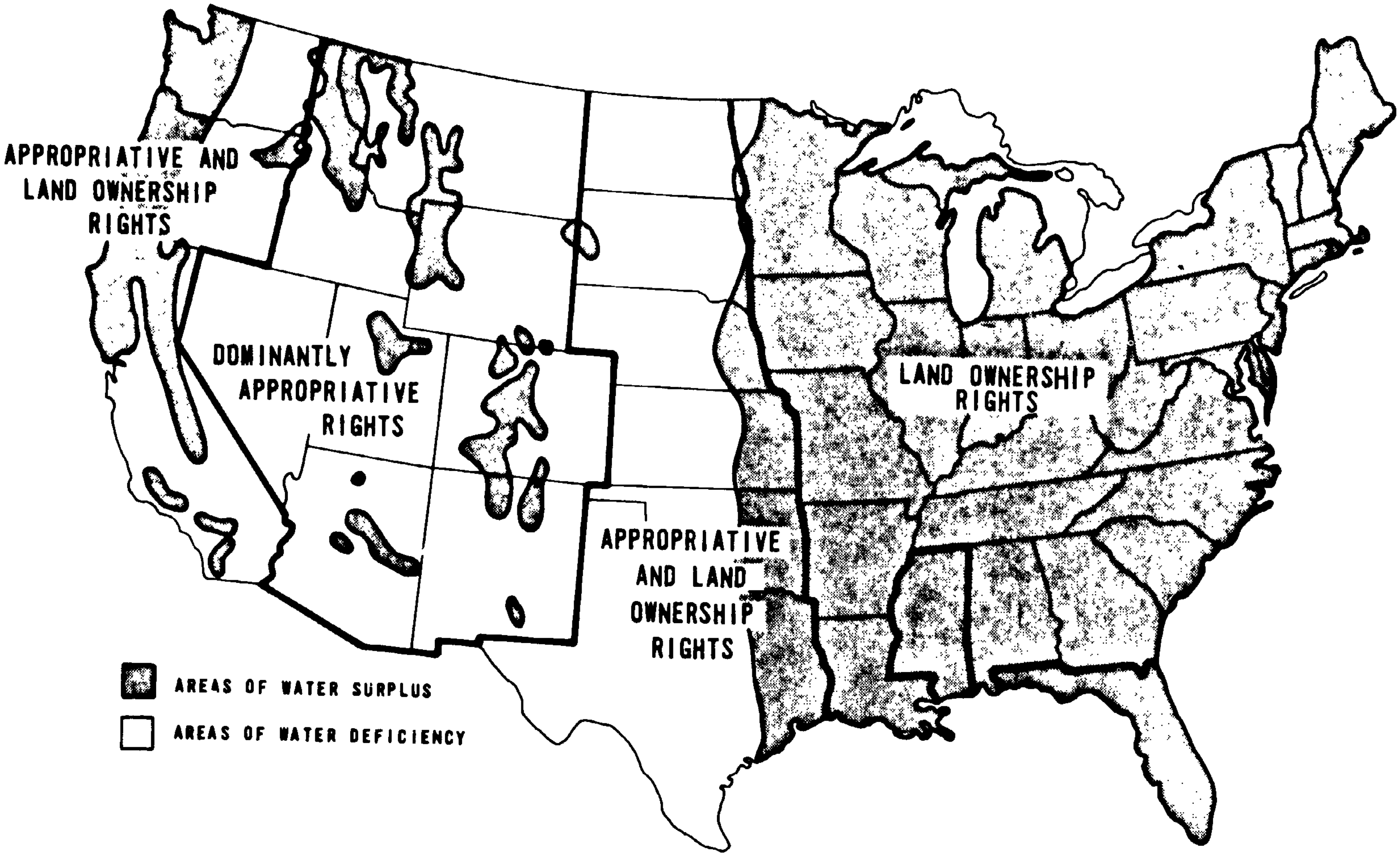


FIGURE 2-10
DOMINANT WATER RIGHTS DOCTRINES AND AREAS OF WATER SURPLUS OR DEFICIENCY

TABLE 2-16
POTENTIAL WATER RIGHTS PROBLEMS FOR LAND TREATMENT ALTERNATIVES[a]

	Land treatment process		
Water definition and water rights theory	Slow rate	Rapid infiltration	Overland flow
Natural watercourses			
Riparian	Unlikely	Unlikely	Unlikely
Appropriative	Likely[b]	Likely[b]	Depends on location of discharge from collection ditch
Combination	Likely[b]	Likely[b]	Depends on location of discharge from collection ditch
Surface waters			
Riparian	Unlikely	Unlikely	Likely[c]
Appropriative	Unlikely	Unlikely	Likely[c]
Combination	Unlikely	Unlikely	Likely[c]
Percolating or ground waters			
Riparian	Unlikely	Possible	Unlikely
Appropriative	Likely	Likely	Unlikely
Combination	Likely	Likely	Unlikely

a. For existing conditions and alternative formulation stage of the planning process only. It is also assumed that the appropriative situations are water-short or overappropriated.

b. If effluent was formerly discharged to stream.

c. If collection/discharge ditch crosses other properties to the natural watercourse.

2.4.2 Surface Waters

For surface waters, riparian and appropriative rights are very similar. If renovated water from a land treatment system crosses private property, a drainage or utility easement will be necessary.

2.4.3 Percolating Waters (Ground Waters)

Water rights conflicts may be caused either by a rise in the ground water table that damages lands adjoining a land treatment system or by the appearance of trace contaminants in nearby wells. In riparian states, the landowner must prove that his ground water is continuous with and down-gradient from ground water underlying the land treatment site. If the alleged damages are not the result of negligent treatment site operation, cause for legal action will be difficult to show. In appropriative states, increases in ground water table elevations would not usually threaten anyone*s appropriative right. Thus, there would be no cause for legal action.

2.4.4 Sources of Information

For larger systems and in problem areas, the state or local water master or water rights engineer should be consulted. Other references to consider are the publications, A Summary-Digest of State Water Laws, available from the National Water Commission 125], and Land Application of Wastewater and State Water Law, Volumes I and II 1126, 27]. If problems develop or are likely with any of the feasible alternatives, a water rights attorney should be consulted.

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